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PERFORMANCE OF THE ELECTRICAL FACILITIES OF THE CZECHOSLOVAK NUCLEAR REACTOR

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PERFORMANCE OF THE ELECTRICAL FACILITIES OF THE CZECHOSLOVAK NUCLEAR REACTOR

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Introduction

The purpose of this article is to inform the reader about the operational experiences with the electrical facilities of the Czechoslovak experimental nuclear reactor at Rez since it has been started up. These experiences may serve the installation and start-up of the Czechoslovak nuclear power station.

The electrical equipment of the reactor consists of the following:

A. System of automatic output control, warning and accident signalization, and accident protection of the reactor.

B. System of electrical distance measuring of the technological values of the reactor.

C. High voltage facilities.

A. The automatic output control of the reactor, warning and accident signalization and accident protection of the reactor.

A correct performance of the automatic output control and protection is based on the data of the ionization chambers, which are sensitive to neutrons and located in dry channels near the active zone of the reactor. The specified isolation resistance between the individual electrodes is 10^{11} ohm (i.e., the isolation resistance of the supply cables must be higher). Regular measuring of the isolation resistance showed that in certain ionization chambers the isolation resistance decreased by as many as two categories. Careful measuring of the isolation resistance of the ionization chambers has to be conducted outside the active zone because the ionization chambers for measuring neutrons are

sensitive even to the gamma radiation which, in the vicinity of the active zone while the reactor is not in operation, reaches relatively high values. If it is not possible due to operational reasons to measure the isolation resistance outside the active area, the effect of the momentary gamma radiation must be taken into consideration in the obtained result. The measured isolation resistance is in this case always lower than the actual resistance. A moderate decrease of the specified value does not necessarily have to be a reason for replacing the ionization chamber. In current practice, the chamber is retained after it has been ascertained that there is no danger of a sudden change of the isolation resistance and as long as the measured values of resistance are at least three categories higher than the load resistance of the ionization chamber at the time of operation.

Measurement of the isolation resistance is not the only criterion of the operational condition of the ionization chambers. The chamber streams caused by the flow of neutrons at certain output levels of the reactor are also measured regularly. The ionization chamber stream is a linear function of the reactor output functions. However, it may happen that even a good ionization chamber will show, in comparison with a preceding measurement, a value of differing by 10%. Such a case occurs due to a change in distribution of the neutron flow in the reactor. In practice, a change in distribution of the neutron flow results, for example, from placing certain material (absorber) for radiation into the channel close to the respective ionization chamber, or by a change in the configuration of the uranium fuel cells of the active zone. If these changes are of a short duration, it is possible temporarily to expect new data from the chamber. If the changes affecting the distribution of the flow of neutrons are long, it is possible (under special conditions) to shift the ionization chamber to a suitable position so that the shown data corresponds to the actual output of the reactor.

The quality of the gaseous contents is determined by the level of the individual ionization chambers, during both the gamma radiation and the neutron radiation. The obtained characteristics of the ionization chamber during the gamma radiation actually proved to be identical to the extent of 100v to 800v, while the operational voltage of the chambers is only 500v. Only in one chamber was it found that the limit of the level was 550v. In the neutron radiation the obtained characterists showed that their extent had an equally good development as they had during the measurement in the gamma radiation.

The data of the ionization chamber must be in continuous accordance with the thermic output of the reactor. Occasional differences were compensated by a change in position of the chambers.

Out of the seven ionization chambers used in the control and protection of the reactor, only two have been put out of operation; this was because of their low isolation resistance. The replacement of the ionization chambers is conducted in an area containing a danger of radioactive radiation and contamination by radioactive aerosols. For that reason it must proceed according to a program prepared beforehand, and under conditions which afford maximum security for the operators. On the whole, it may be said that the attention given to the properties of the ionization chambers enables their best utilization, and is a guarantee of the data reliability. General graphic representation of the necessary measurement of the ionization chambers is presented in Illustration 1 (a, b, c).

The proper system of automatic output control fulfills its task very efficiently. The most important property of this control--the stability of the maintained output--entirely corresponds to the original calculation in which the service-mechanism synthetic method was applied. The control measuring during the check-up showed that the properties of the individual members of the regulation loop have not basically changed; however, in the amplidyne the value of the inner resistance had to be slightly adjusted. The stability of the regulation loop is imporved by a regulatory back-coupling. The back-coupling effects produced by the changes in the fuel temperature and the combustion and debasement of the fuel cells have a great time constant and do not come in force.

The accident prevention system works reliably. There have been few stoppages due to defects of the electrical (electronic) equipment or incorrect manipulation. The realiability of this equipment is checked by irregular, artificially set accident signals. Due attention must be given to the accident-rods complex driving system. The incidence of the rods must be rapid but soft, if possible. Its speed, measured by an electric stop watch, remains the same as when the reactor was started. This driving system is regularly checked and adjusted from time to time.

There is one accident worth mentioning. The rectifier supplying the ionization chamber of the automatic regulator lost the outside circuit voltage. The direct current voltage of this rectifier was slowly going down because of the condensers of the filtration section. The ionization chamber, supplied by a decreasing potential, produced decreasing current. Thus, were created in the automatic regu-

lator circuit conditions of a diminishing output of the reactor. The control rod of the automatic regulation responded to this false signal in such a way that it was receded from the active zone. This caused a growing output of the reactor. As soon as the output reached the maximum permitted limit, the accident rods interfered. The defect was removed by means of installing a suitable voltage relay in the rectifier.

A reliable and safe function of the electrical facilities is, among other things, conditioned by good grounding. The reactor has three ground circuits:
(a) high voltage-supplied equipment grounding
(b) laboratory switch-board grounding
(c) automatic control and reactor protection grounding.

The above grounds are interconnected at specific points. Control measuring of the resistance of these grounds is important, especially in the ground of the reactor control (this ground is placed between the reactor body on one side and the control center with the electronic apparatuses on the other).

A deteriorated quality of this ground would result in an unreliable functioning of the ionization chamber flows. Control measuring of the ground resistance did not indicate any changes in comparison with the data at the time of the start-up of the reactor.

B. Electrical distance measuring of the technological quantities of the reactor.

The instruments whose vital organs are placed in radioactive media must receive continuous, extraordinary, preventive care. The defectiveness and probability of necessary action in a radioactive environment during the operation of the ractor is thus reduced; this is, from the viewpoint of the workers' safety, very advantageous. The reliability of the instruments measuring the non-electrical quantities is an important factor even in detecting defects in the technological circuits of the reactor. Here are two practical examples. In the hot chambers of the reactor the samples that were exposed to radiation are processed. For safety reasons, sub-pressure must be maintained there. It happened that the sub-pressure gauge showed a lower value. Since the gauge was in excellent condition, it became evident that the error was in the hot chambers themselves. It was discovered that during the manipulation in the hot chambers some outlet was opened for awhile. In another case, the instrument recording the flow of distilled water in the primary cooling circuit through the refining filter indicated gradually decreasing values, and finally went down to zero. Since ever this instrument was quite reliable, attention was concentrated on the filter. It was discovered that the mechanical

properties of the refining filter media gradually deteriorated; this caused the flow to stop.

Control gauging and adjusting of non-electrical quantity measuring instruments usually cannot be carried out, due to the operation of the reactor. This work must be therefore done at a time when the reactor is out of operation. The control gauging data showed that the accuracy and sensitivity of the instruments and their organs have not basically changed. Not even the parts placed in radioactive media, e.g., the platinum resistance thermometers, showed substantial changes. No deviation from the standard values has been noted in the cable connections between parts of instruments and their indicators or recorders.

In the field of measuring, after the necessary operational experience two functions were added in comparison with the original project. They are the measuring of the pH and the conductivity of distilled water in the reactor colling circuit. Furthermore, there was designed and installed a reactor-output computer from which data on the consumption of the fuel cells are obtained. In certain recorders, an improvement was made by replacing the steel nibs which, in sudden transitional conditions, tended to tear the paper tape with black-lead points.

Operational experience shows that in the designing of reactors which contain a number of measuring organs, it is desirable to think of the telephone connection for the rapid supply of information needed by the control and gauging services. It means to provide both ends of the respective pairs of conductors, both in the cables that connect the organ of the instrument in question and its indicator located in the control center, with outlets for a rapid plugging-in of microtelephones at the measuring points.

In the operation of the Czechoslovak reactor, good experience was collected regarding the average number of times per year that maintenance, repairs, and gauging of one instrument are necessary. These data may serve as a guide for the same works in the first Czech nuclear power station with respect to planning of the number of workers.

C. High voltage facilities

In the high voltage equipment, which is (as a majority of other equipment) mostly manufactured in the USSR, there have been encountered differences in the Czechoslovak and Soviet safety standards. The facilities used have been subjected to exceptions which place increased demands on the operators.

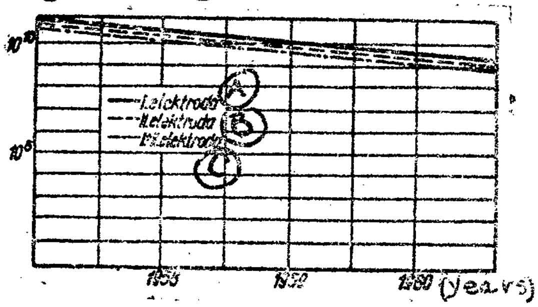
A large part of the high-voltage equipment has a distance control and a signal system, such as, experiment canal

outlet shutters, slide-valves and pumps of the distilled water primary cooling circuit, thermic column, etc. In these circuits there are a great number of terminal switches, because a failure of the installations located in the area within the reach of the radioactive radiation during operation is dangerous. Due to safety reasons, it was suggested to install a remote electrical control of the device which inserts samples into the experimental channel. The original system was equipped with a local control only.

It is worthwhile to mention the good vitality of the movable light reflector which is placed in the water over the active zone and is exposed simultaneously to the effects of water and radioactive radiation.

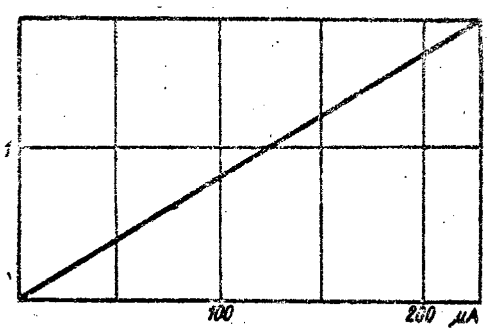
The emergency electric sources supplying certain important sections of the reactor in the event of a failure in the outside current circuit perform satisfactorily. An improvement was made; namely, the emergency electric source was connected with the power outlets of the experimental radiation channels of the reactor. This made it possible to close, if necessary, the open channel when the electric current supply is interrupted.

Thanks to preventive care, the stoppage rate of the high-voltage facilities has remained at a minimum.



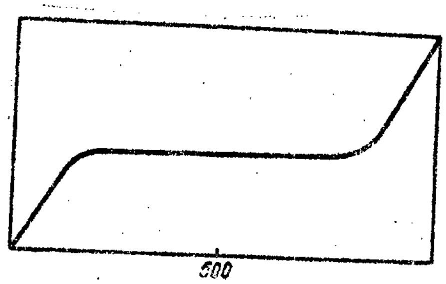
Isolation resistance of the ionization neutron chamber electrodes [Ω]

A) 1st electrode
B) 2nd electrode
C) 1st and 2nd electrodes



Reactor output /MW/

Ionization chamber flow



(c) Ionization neutron chamber flow at a constant output of the reactor [μA]

Voltage of the direct current source of the chamber

Illustration No. 1: General graphs of the control measuring of the ionization neutron chambers.

(a) Measuring of the isolation resistance between individ-electrodes and the frame and between electrodes themselves.
(b) Measuring of the current with relation to the output of the reactor.
(c) Measuring of the output level at a given constant output of the reactor.

Measuring of the types a, b, is performed regularly.

Conclusions

This article includes only a part of the experience gained during the operation of the electrical facilities of the Czechoslovak reactor. Mention should be made of the good quality of Soviet measuring and industrial instruments, which have proved very suitable in the long operations of the reactor which place great demands on the bearings of the recorder motors, transmission gears, vibrators of the direct current intensifiers, etc.

The performance of the electrical facilities, machinery, and dosimetric equipment with as few stoppages as possible, is the basic condition of the experimental, re-research, and production work at the reactor site. Experience shows that minimum stoppage depends on well-contemplated, planned, consistent, and detailed preventive maintenance. On the whole it may be said that the low and high voltage electrical facilities of the first Czechoslovak reactor have performed reliably since the start-up. It never happened that, owing to a defect, these facilities had to be put out of operation for a long time. The table following gives the number of minor accident stoppages and the reasons during the three years of the reactor's opera-

tion. For the sake of completeness, there were also included in this table accident stoppages of the reactor due to an interruption of the electric current supply from the outside circuit, by a decrease of its voltage, and by ground short-circuits; these are factors which in no way can affect the proper electrical facilities of the reactor or the operators. Over the three years there were 28 cases involving external causes of this kind. The number of other accidents is really meaningless and, at the same time, shows a decreasing trend. In the first year there were six accidents, in the second, five, and in the third, four. This is a proof of the good quality of all the electrical equipment and the responsible work of the technical staff.

[See Table 1 on following page]

Table 1. Accident Stoppages of the VVR-S Czechoslovak Experimental Reactor in the Electrical Facilities and Circuits During the First Three Years of Operation

		1957			1958											
		10	11	12	1	2	3	4	5	6	7	8	9	10	11	12
A	Přerušení venkovní dodávky el. proudu															3
B	Zemní zkrat	1														
C	Snížení napětí venkovní sítě											1				
D	Chybná manipulace	1														
E	Poruchy v elektronických zaříz. aut. regulace a ochrany reaktoru				1									1		
F	Poruchy v obvodech pro měření neelektr. veličin								1							
G	Ztráta stejnosměrného napětí pro pohon reguláč. tyčí	1														
H	Ztráta stejnosměrného napětí pro havarijní tyče	2														
I	Poruchy v silnoproudých zařízeních															

		1959											
		1	2	3	4	5	6	7	8	9	10	11	12
A	Přerušení venkovní dodávky el. proudu	1	1	1		1	3	3			1		
B	Zemní zkrat						2						
C	Snížení napětí venkovní sítě												
D	Chybná manipulace												
E	Poruchy v elektronických zaříz. aut. regulace a ochrany reaktoru												
F	Poruchy v obvodech pro měření neelektr. veličin												
G	Ztráta stejnosměrného napětí pro pohon reguláč. tyčí												
H	Ztráta stejnosměrného napětí pro havarijní tyče		1					1					
I	Poruchy v silnoproudých zařízeních	1	1										

		1960									Total
		1	2	3	4	5	6	7	8	9	
A	Přerušení venkovní dodávky el. proudu	2	1		3	1				1	22
B	Zemní zkrat										3
C	Snížení napětí venkovní sítě			2							3
D	Chybná manipulace			1							2
E	Poruchy v elektronických zaříz. aut. regulace a ochrany reaktoru						1				3
F	Poruchy v obvodech pro měření neelektr. veličin										1
G	Ztráta stejnosměrného napětí pro pohon reguláč. tyčí	2									3
H	Ztráta stejnosměrného napětí pro havarijní tyče										4
I	Poruchy v silnoproudých zařízeních										2

Legned: A) Interruption of supply from the outside power sources; B) Earth short circuit C) Decrease in voltage of the outside circuit; D) Incorrect manipulation; E) Defects in the electronic mechanisms of the automatic control and protection of the reactor; F) Defects in circuits of measuring the non-electrical quantities; G) Loss of direct current voltage for control rods driving; H) Loss of direct current voltage for accident rods driving; and I) Defects in the high voltage facilities.

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